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RUNNING TITLE: EFFECTS OF INTERRUPTIONS BY PAIN

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Abstract

Background and aims: Suspending an ongoing activity with the intention to resume it again later is a natural response to pain. This response facilitates coping with the pain, but it may also have negative consequences for the resumption and performance of the activity. For example, people with pain problems are often forced to take a break from doing their household chores because of their pain. They might delay resuming their chore, eventually needing longer time to finish it. We investigated how activity interruptions by pain influence the pattern of subsequent activity performance. We expected that when an activity is interrupted by pain (compared to nonpain), people spend longer time away from the activity, need longer time to complete it, and are less motivated to perform it.

Methods: Sixty healthy volunteers performed an ongoing task that required them to make joystick movements in different directions according to a specific rule. Occasionally, participants received either a painful electrocutaneous stimulus or a non-painful and non-aversive auditory stimulus (between-subjects) as an interruption cue. The interruption cue was followed by the temporary suspension of the ongoing task and the initiation of a different activity (interruption task). The latter required the categorization of cards and had a maximum duration, but participants could also stop it earlier by pressing a button. We measured time away from the (interrupted) ongoing task, total time to complete the ongoing task (including the interruptions), and self-reported motivation to perform both the ongoing as well as the interruption task.

Results: Groups did not differ in the time away from the ongoing task, total time to complete the ongoing task, or self-reported motivation to perform the two tasks.

Conclusions: Activity interruptions by pain did not impair the pattern of activity performance more than activity interruptions by non-pain. Potential explanations and suggestions for future research are discussed.

Implications: Interrupting ongoing activities is a common response to pain. However, activity interruptions by pain do not appear to influence the pattern of activity performance in a different way than activity interruptions by pain-irrelevant external stimuli.

Keywords

pain; (activity) interruption; task performance; performance pattern; task interference

1. Introduction

Pain is an evolutionary signal of threat that urges us to act in order to escape from or avoid danger (1,2). A common response to pain is to suspend ongoing activities for some time, whilst intending to resume and complete them later (3). Although this response may facilitate pain management, it can also have negative consequences for the activity.

The events that take place when an activity is interrupted by pain are described in a theoretical model (3) informed by the interruption literature outside the field of pain (such as the Memory for Goals model, (4), and the stage model of Boehm-Davis and Remington (5)).This literature shows that (pain-irrelevant) interruptions mostly disrupt performance (e.g., (6–9). Activity interruptions by pain have also been shown to impair quality of performance, though not more so than interruptions by non-painful stimuli (10,11). Existing evidence indicates that activity interruptions by pain may also influence the way that people perform an activity. For example, people with pain complaints report continuing work outside working hours on days that they experience activity interruptions by pain (12). Further, healthy people scoring high in pain catastrophizing are shown to persist less in an activity that is interrupted by pain, compared to when it is not interrupted at all (13). Whether activity interruptions by pain influence the pattern of activity performance differently than activity interruptions by non-pain, however, is unknown.

Whereas the natural tendency is to avoid pain and pain-related activities (14,15), especially when these are not highly valued (16), at the same time, interrupted activities urge their completion (1). As a result, people might shift between approaching and avoiding the activity. When the activity cannot be completely avoided (e.g., by being delegated to another person), this may be expressed as prolonged time away from the activity as a temporary solution to the conflict or until pain subsides (3). The same is not expected for interruptions by non-painful and non-aversive

stimuli, in which completing the (unavoidable) task is expected to be prioritized over the interruption. Activities that are interspersed with long interruptions are expected to also need long time for their completion, unless compensatory strategies are used to counteract this negative effect (7,17). Finally, given that the threat value of pain enhances its disruptiveness (e.g., (1,15,18)), effects are expected to be more prominent amongst people who experience pain as threatening, such as high pain catastrophizers.

This experiment investigated how activity interruptions by pain influence the pattern of activity performance. Healthy participants performed an ongoing task, during which they occasionally received either painful or non-painful and non-aversive interruption cues, followed by ongoing task suspension and initiation of an open-ended interruption task. We expected that participants interrupted by pain would spend longer time on the interruption task, and therefore on the activity as a whole. Alternatively, we considered that longer time away from the interrupted task would not be reflected on longer total time on task, because of engagement in compensatory actions. Finally, people interrupted by pain were expected to report lower motivation to perform the interrupted task. Effects were expected to be stronger amongst high pain catastrophizers.

2. Methods

2.1 Participants

Sixty-three healthy volunteers participated in the experiment. Three participants were excluded from the analyses because of technical problems during the lab session, thus leaving our final sample with sixty participants. Exclusion criteria were checked by means of self-report and comprised pregnancy, past or present diagnosis of a psychiatric and/or neurological disorder,

current use of anxiolytic and/or antidepressant medication, cardiovascular disease, acute or chronic pain, presence of an electronic implant (e.g. cardiac pacemaker), imperfect command of the Dutch language, and impaired (uncorrected) eyesight. Participants were University of Leuven students or employees, who participated in the study on an informed consent basis and who received monetary compensation or partial course credit for their participation.

2.2 Interruption cues

Painful stimuli. Electrocutaneous stimuli (square-wave; duration: 700 msec; frequency: 10 Hz) served as the interruption cues for the Pain group. The electrocutaneous stimuli were generated by a DS5 constant current stimulator (Digitimer Limited, Hertfordshire, UK) and delivered through two 8 mm Ag/AgCl surface electrodes (Bilaney, Düsseldorf, Germany). The electrodes were filled with electroconductive gel (K-Y gel, Johnson & Johnson) and applied on the dorsal side of the participant's non-dominant wrist with an inter-electrode distance of ~1 cm. Before electrode attachment, the participant's skin was scrubbed with a commercially available scrub cream to reduce skin resistance.

Stimulus intensity was individually determined in such a way that the stimuli required some effort to tolerate. After electrode application, the experimenter administered a series of electrocutaneous stimuli, starting with an intensity of 0.2 mA and increasing in steps of 0.4 mA. This procedure continued until the participant did not wish to be administered a higher stimulus, or until they had rated the last stimulus as a 9 on an 11-point "effort to tolerate" scale (0="no effort at all"; 10="maximum effort I can exert"). Several times throughout the stimulus series (including upon the last stimulus), participants were also asked to rate the painfulness and unpleasantness of the stimulus on 11-point numerical scales (0="not at all painful/unpleasant"; 10="the most

painful/unpleasant that I can imagine"). The average stimulus intensity used in this study was 3.8 mA (*SD* = 1.7, range 0.8-8.6).

Nonpainful stimuli. Auditory stimuli (doorbell sound; duration: 700 msec; frequency: 16000 Hz) served as the interruption cues for the Nonpain group. The auditory stimuli were presented binaurally by means of a standard headset (Philips, Amsterdam, The Netherlands).

Stimulus intensity was individually determined in such a way that the auditory stimulus was easily perceivable, but not aversively loud. The participant wore the headset and was presented with the auditory stimulus several times, with the volume adjusted every time until the participant stated that the sound was easy to perceive but not too loud. To match the procedure with that of the Pain group, participants also rated the effort to tolerate, the intensity and the unpleasantness of the sound on three 11-point numerical scales similar to the ones used for the Pain group.

2.3 Experimental task

A joystick paradigm (based on (19)) was developed with the aim to simulate a simple motoric task with a clearly defined goal, the pursuit of which is occasionally interrupted in response to pain. The specific task components were as follows (see also Figure 1):

[INSERT FIGURE 1 SOMEWHERE ABOUT HERE]

Ongoing task. Participants moved a joystick in four directions (to the left, to the right, to the screen and to themselves). Each movement corresponded to one of four locations (left, right, up, and down) on the computer screen. On each location there were four coloured (two blue, two yellow) rectangles. The screen background was grey (Figure 1a). At the central point between the

four locations, a fixation cross was presented, indicating when participants were required to move the joystick to one of the locations. When the movement was registered, the fixation cross disappeared and the first coloured rectangle at that location became black and thus unavailable. After an intertrial interval of 2500 msec, the next rectangle at that location became available. Each participant was assigned a target colour (blue or yellow, counterbalanced) and was instructed to prioritize movements to locations with available rectangles of that colour. For example, participants with blue as their target colour were required to first "free up" and reach as many blue rectangles as they could, before making movements to locations with available yellow rectangles. A vertical bar was presented on the left side of the screen and indicated the participant's progress in the ongoing task. After every movement towards a target colour rectangle, the bar was filled with the target colour (Figure 1b) in such a pace, that it was completely filled only when the participant had made movements to all target colour rectangles of the whole task. The task consisted of 20 blocks of 16 movements each. When all rectangles of a block had become unavailable, a new block began immediately, thus giving participants a sense of continuity during the task.

On ten randomly preselected trials throughout the task, an interruption cue (painful electrocutaneous or non-painful non-aversive auditory stimulus) was administered. It was administered during the joystick movement, with its onset being when the (invisible) joystick cursor left the fixation cross. Upon completion of the movement and the interruption cue, the ongoing task was suspended and the interruption task was initiated.

Interruption task. The interruption task aimed at engaging participants in a similar way during the interruption, and consisted of a simple variation of the Wisconsin card sorting task (20). In each trial, three cards were presented on a black background; one card was always presented at

the center of the screen, whereas the other two cards were presented either on its left and right (horizontal version; 50% of the interruptions), or above and below it (vertical version; 50% of interruptions) (Figure 1d). Each card depicted one to four identical geometrical shapes, in one of four different colours (e.g. three green stars). There were five different types of shapes. Participants were instructed to move the joystick towards the card that depicted the same geometrical shapes as the middle card. This categorization rule was known to participants and did not change throughout the task. The cards remained on the screen until a response had been given, or for 7000 msec. Intertrial interval was 1500 msec.

Each interruption continued for a maximum of 2 minutes, but participants could also stop it earlier by pressing a Stop-button on the joystick. After pressing the Stop-button or after the 2 minutes had passed, the interruption task stopped and the ongoing task started again with the next trial and the same screen configuration (i.e., the same available rectangles and status of vertical bar) as it was when interrupted (Figure 1e). Participants were instructed to perform both the ongoing as well as the interruption task as fast and as accurately as possible.

2.4 Measures

2.4.1 Behavioural measures

Our main outcomes were (1) the time that participants spent on the interruption task (i.e., time spent away from the interrupted ongoing task), and (2) the total time taken to complete the experimental task (i.e., the time from the first to the last trial of the ongoing task, including the time spent on the ten interruptions). Additionally, we also measured (3) the number of times that participants pressed the Stop-button to end the interruption.

2.4.2 Self-report measures

In order to investigate the role of *pain catastrophizing*, we administered the Pain Catastrophizing Scale (PCS; (21,22). The PCS measures rumination about pain, magnification of pain sensations, and helplessness about the pain. Participants are asked to consider previous painful experiences and to rate each of 13 items on a 0 ("not at all") to 4 ("all the time") scale. The Dutch version of the PCS has previously shown good psychometric qualities in non-clinical samples (22) and had a Cronbach's α=.91 in our sample (n=62).

Participants rated their *motivation to perform the ongoing and the interruption task*, namely the degree to which they would be willing to perform each of the two tasks again, on two 11-point numerical scales (0="not at all", 10="to a very high degree").

For our manipulation check, participants rated the *interruption cue characteristics*, specifically the painfulness (for the Pain group only), unpleasantness, and threat value of the interruption cue on 11-point numerical scales (0="not at all", 10="to a very high degree").

To explore the effects of our experimental manipulations on *state affect*, we administered the Self-Assessment Manikin (SAM; (23)), and the state version of the Positive and Negative Affect Schedule (PANAS; (24,25)). The SAM version we used consisted of three 9-point pictorial scales, each of which measures one of the basic affective dimensions, namely pleasure, arousal and dominance. For the PANAS, participants read 10 adjectives describing positive affect and 10 adjectives describing negative affect, and were required to rate the degree to which each one of them described how they felt at that moment on a 5-point scale.

Other measures[1] were administered for exploratory reasons and will thus not be further discussed.

[1] These comprised a Situational version of the Pain Catastrophizing Scale (Pain participants only; (43)) within the session, and the Fear of Pain Questionnaire (44,45), Prospective and Retrospective Memory Questionnaire (46,47),

2.5 Procedure

The study consisted of a lab session and an online questionnaire session that took place one week later. To protect integrity, the experiment was presented as an investigation of visuospatial skills. The study protocol was approved by the Ethics Committee of the Department of Psychology of the University of Leuven (reg. nr. S54157) and the Medical Ethics Committee of the University Hospital Leuven (reg. nr. ML8125). During the lab session, participants were tested individually in a dimly lit room, as follows:

Introduction. Upon arrival to the lab, participants were allocated to one of the two interruption cue conditions (painful vs. non-painful) and one of the two target colours (blue vs. yellow) according to a blocked randomization procedure, and read information about the condition they belonged to. Exclusion criteria were checked and participants provided informed consent, demographic information, and the first state affect measurement (SAM and PANAS).

Interruption cue calibration/ familiarization. The experimenter applied the electrodes on the wrist of the participant's non-dominant arm (Pain group) or asked the participant to wear the headset (Non-Pain group), and the stimulus intensity to be used during the task was individually determined (see *2.2 Interruption cues*). Participants filled in the second state affect (SAM only, due to the length of the PANAS).

Experimental task. Participants received oral and written task instructions. First, they read instructions about the ongoing task and practiced one block of 16 movements. Subsequently, they read instructions about the interruption task and the use of the Stop-button, and practiced a maximum of 16 trials. After the fourth trial, participants could also practice using the Stop-button. The practice phase included visual accuracy feedback, trials and ITIs longer than in the test phase,

Goal Pursuit Questionnaire (48), Prevention/ Promotion Scale (49) and Positive and Negative Affect Schedule, Trait version, in an online questionnaire session that took place one week after the participant came to the lab.

and no interruption cues. Participants were informed that, in the test phase, interruption cues would be administered during the ongoing task but never during the interruption task. Participants were told that they were required to perform a certain number of trials for the ongoing task, as they would be "finished with the task when the [vertical] bar was completely filled [with colour]". They were also told that "every time [the interruption task started] they could perform [it] for a maximum of two minutes" but they could actually "determine [themselves] how many cards to categorize and when to stop [the interruption task]" by pressing the Stop-button. Note that the ongoing and interruption task were presented as the "colour" and the "card" task, respectively, in order to not be charged with differential motivational value or importance. It was assumed, however, that the goal of filling the bar with colour would motivate participants to resume and complete the ongoing task. After the instruction and practice phase, participants performed 20 blocks of the ongoing task, 10 of which included an interruption cue followed by a maximum of two minutes on the interruption task. To keep the procedure as similar as possible across the two groups, Pain group participants were also asked to wear the headset while performing the computer task, allegedly to block external background noise. However, Pain group participants received no auditory stimulation.

End session. Upon task completion, the experimenter removed the electrodes and/or headset. Then, participants rated the characteristics of the interruption cue, their motivation to perform each task, and their state affect (SAM and PANAS), and chose their compensation. Participants were debriefed about the real aims and hypotheses of the study when the whole sample had been tested.

2.6 Equipment

The computer task was programmed with Affect, version 4.0 (26) and run on a Windows XP computer (DELL Optiplex 755) with an Intel Core 2 Duo (2.33 GHz) processor. Participants viewed the task on a DELL 19-inch screen with a 1024 x 768 pixel resolution, and performed it by means of an Attack™ 3 Joystick (Logitech, Lausanne, Switzerland). The online platform Limesurvey (27) was used for the questionnaire session.

2.7 Statistical analyses

To compare the two groups with regards to their characteristics and the ratings of the interruption cue, we performed a series of χ^2-tests and unpaired sample *t*-tests with interruption cue group (2: pain vs. non-pain) as the independent variable.

For our main hypotheses, we expected to see longer time on the interruption task, longer total time to complete the experimental task, and lower self-reported motivation to perform the ongoing task in participants who received the painful interruption cue, compared to participants who received the non-painful and non-aversive interruption cue. To investigate these expectations, we performed the following analyses. First, a mixed Analysis of Variance (ANOVA) with interruption cue group (2: pain vs. non-pain) as the between-subjects factor and interruption number (10: interruption 1 to interruption 10) as a within-subjects factor, on the time on the interruption task. Second, a one-way ANOVA with interruption cue group (2: pain vs. non-pain) on the total time to complete the experimental task. Third, a mixed ANOVA with interruption cue group (2: pain vs. non-pain) as the between-subjects factor and task type (2: ongoing task vs. interruption task) as the within-subjects factor on the self-reported motivation. In addition, we performed a one way ANOVA with interruption cue group (2: pain vs. non-pain) on the number

of Stop-Button presses, to explore whether groups would also differ in this respect. In order to investigate the role of pain catastrophizing in the examined relationships, we included the centered PCS score as a continuous variable in the above analyses. These analyses yielded no essentially changed or additional statistically significant results, and are therefore omitted from the main manuscript in the interest of brevity, but are presented in Supplementary Material.

In addition, in order to explore whether and how state affect changed throughout the session, we subjected the SAM and PANAS ratings to two separate mixed ANOVAs with interruption cue group (2: pain vs. non-pain) as the between-subjects factor and time point (for SAM, 3: beginning session, after calibration, end session; for PANAS, 2: beginning session, end session) as the within-subjects factor.

Due to violations of the sphericity assumption, multivariate test statistics (Pillai's Trace) are reported (28–30). Where relevant, mean differences with their 95% confidence intervals are reported. The reported effect size is partial eta squared (η_p^2) with its 90% confidence interval (31). Missing values (one participant did not fill in the online questionnaires) were excluded listwise. Four participants were excluded from the analyses on the total time to complete the experimental task, because of a programming error that prevented the accurate registration of the total duration, thus leaving the sample for these analyses with 56 participants. This error had no impact on registration of other data. Analyses were performed with SPSS version 22.0 (32). Note that due to the novelty of the study we lacked prior data to base a thorough a priori power analysis on. However, we performed an ad hoc power analysis with G*Power 3.1.9.2 (33). This analysis indicated that our study was adequately powered to detect a large effect size (required $n = 30$), but not necessarily a medium effect size (required $n = 70$) (calculations made for Mixed ANOVA with

2 groups and 10 measurements correlated at 0.5, α of 0.05 and a power at the conventional level of 0.80).

3. Results

3.1 Group characteristics

The gender ratio, age, and self-reported pain catastrophizing of each group are described in Table 1. The groups did not differ in these characteristics (see Table 1). The mean PCS scores are similar to these previously obtained in similar samples (16.6, *SD* = 7.8; Van Damme et al., 2002).

3.2 Interruption cue characteristics

The painfulness, unpleasantness and threat value of the electrocutaneous stimulus were rated as moderate to high (>5.9) (see Table 2). Moreover, the electrocutaneous stimuli were rated as significantly more unpleasant and threatening than the auditory stimuli.

[INSERT TABLES 1 AND 2 SOMEWHERE ABOUT HERE]

3.3 Interruption effects

3.3.1 Time on the interruption task

Figure 2 depicts the average time spent on the interruption task across the experimental session, per group. The time spent on the interruption task decreased over time (main effect interruption number: $F(9, 50) = 3.97$, $p = .001$, $\eta_p^2 = .416$ [.135, .469]), but this did not depend on the interruption cue group (main effect: $F(1, 58) = 0.64$, $p = .429$, $\eta_p^2 = 0.11$ [0, .09]; interruption cue

group*interruption number: $F(9, 50) = 1.89$, $p = .075$, $\eta_p^2 = .254$ [0, .296]). Exactly because the interruption cue group did not have a statistically significant effect, we do not interpret the seeming group difference in the first interruption.

[INSERT FIGURE 2 SOMEWHERE ABOUT HERE]

3.3.2 Total time to complete the experimental task

The average total time to complete the experimental task (i.e., from the first to the last ongoing task trial including the ten times the participants performed the interruption task) was 1627 seconds (*SD* = 350, range 1210-2406) for the Pain group, and 1689 seconds (*SD* = 337, range 1228-2404) for the Non-pain group. The difference between the two groups was not statistically significant, $F(1, 54) = .45$, $p = .504$, $\eta_p^2 = .008$ [0, .086].

3.3.3 Self-reported motivation

Participants reported a low to moderate motivation to perform again the ongoing task (Pain group: mean 3.76, *SD* = 2.63, range 0-8; Non-pain group: mean 3.87, *SD* = 2.20, range 0-9) and the interruption task (Pain group: mean 5.03, *SD* = 2.81, range 0-9; Non-pain group: mean 4.39, *SD* = 2.14, range 0-9). Motivation to perform again the interruption task was higher than that for the ongoing task (main effect task type: $F(1, 58) = 9.51$, $p = .003$, $\eta_p^2 = .141$ [.030, .276]; mean difference 0.90, 95% CI [0.31, 1.48]), but this did not differ for the two interruption cue groups (main effect: $F(1, 58) = .23$, $p = .636$, $\eta_p^2 = .004$ [0, .067]; interruption cue group*task type, $F(1, 58) = 1.71$, $p = .196$, $\eta_p^2 = .029$ [0, .127]).

3.3.4 Stop-button presses during the interruption task

We also explored for potential differences in the number of times that participants stopped the interruptions themselves (possible maximum was 10 times), instead of allowing them to continue to the full 2 minutes. On average, participants pressed the Stop-button 8.93 (*SD* = 2.62, range: 0-10) times in the Pain group and 8.58 (*SD* = 2.62, range: 0-10) times in the Non-pain group. This difference did not reach statistical significance , $F(1, 58) = .27$, $p = .606$, $\eta_p^2 = .005$ [0, .070]. The vast majority of participants ($n = 40$, 66.7%; 20 of the Pain group, 20 of the Non-pain group) pressed the Stop-button all 10 times, whereas only few participants ($n = 3$, 5%; 2 of the Pain group, 1 of the Non-pain group) never pressed the Stop-button.

3.4 Self-reported state affect

We also explored whether and how state affect changed throughout the session (see Table 3). Below we discuss each (sub)scale separately.

[INSERT TABLE 3 SOMEWHERE ABOUT HERE]

SAM Pleasure. In general, participants reported moderate to high levels of pleasure. A main effect of time point, $F(2, 55) = 12.04$, $p < .001$, $\eta_p^2 = .305$ [.129, .430], was qualified by a significant interruption cue group*time point interaction, $F(2, 55) = 6.98$, $p = .002$, $\eta_p^2 = .202$ [.051, .331]. The Pain group participants reported lower pleasure than the Non-pain group participants after the calibration, $p = .026$ (mean difference -0.69, 95% CI [-1.29, -0.09]), but not at the beginning, $p = 0.69$, or end of the session, $p = 0.729$. There was no main effect of interruption cue group, $F(1, 56) = .83$, $p = .368$, $\eta_p^2 = .015$ [0, .101].

SAM Arousal. The reported level of arousal was low. Analyses yielded a significant effect of time point, $F(2, 55) = 7.3$, $p = .002$, $\eta_p^2 = .21$ [.056, .339], superseded by a significant interruption cue group*time point interaction, $F(2, 55) = 10.52$, $p < .001$, $\eta_p^2 = .277$ [.106, .404]. Pain group participants reported significantly higher arousal than Non-pain group participants after the calibration, $p = .012$ (mean difference 1.16, 95% CI [0.27, 2.06]), but not at the beginning, $p = .754$, or end of the session, $p = .071$. There was no effect of interruption cue group, $F(1, 56) = 3.03$, $p = .087$, $\eta_p^2 = .051$ [0, .166].

SAM Dominance. Participants reported a moderate level of dominance. There were no statistically significant effects (main effect interruption cue group: $F(1, 56) = 2.08$, $p = .155$, $\eta_p^2 = .036$ [0, .142]; main effect time point: $F(2, 55) = 0.59$, $p = .559$, $\eta_p^2 = .021$ [0, .091]; interruption cue group*time point: $F(2, 55) = 2.69$, $p = .077$, $\eta_p^2 = .089$ [0, .202).

PANAS Positive. The reported levels of positive affect were moderate, and appeared to decrease throughout the session, $F(1, 58) = 35.24$, $p < .001$, $\eta_p^2 = .378$ [.214, .503] (mean difference -3.57, 95% CI [-4.77, -2.37]). This did not depend on the interruption cue group (main effect: $F(1, 58) = 1.69$, $p = .199$, $\eta_p^2 = .028$ [0, .127]; interruption cue group*time: $F(1, 58) = 0.6$, $p = .443$, $\eta_p^2 = .01$ [0, .089]).

PANAS Negative. Participants reported rather low levels of negative affect. A main effect of time point, $F(1, 58) = 7.68$, $p = .008$, $\eta_p^2 = .117$ [.018, .249], was superseded by an interruption cue group*time point interaction, $F(1, 58) = 7.07$, $p = .01$, $\eta_p^2 = .109$ [.015, .239]. Specifically, negative affect decreased across the session for the Non-pain group, $p < .001$ (mean difference -1.68, 95% CI [-2.54, -0.82]), but not for the Pain group, $p = 0.938$ (mean difference -0.03, 95% CI [-0.92, 0.85]. There was no main effect of interruption cue group, $F(1, 58) = 0.59$, $p = .445$, $\eta_p^2 = .01$ [0, .089].

Taken together, our results indicate a persistence of negative affect throughout the lab session for participants who received the painful interruption cue. These participants also experienced lower pleasure and higher arousal than participants who received the non-painful interruption cues, but only immediately after the calibration phase, pointing to a potential novelty effect of the painful stimulus that wore out during the experimental task.

4. Discussion

Although interrupting ongoing activities is a natural response to pain (1), the effects of activity interruptions by pain on the subsequent pattern of activity performance have been scarcely investigated. The aim of the present experiment was to shed light on how people perform simple tasks that are interrupted by pain. Healthy volunteers performed an ongoing task that was occasionally interrupted by either a painful electrocutaneous stimulus or a non-painful and non-aversive auditory stimulus, followed by an interruption task. The latter had a maximum, but not a fixed duration. We expected that participants whose activity was interrupted by pain would exhibit an activity performance pattern comprising longer breaks from the interrupted (and pain-relevant) activity, and would therefore also need more time to complete the activity, as compared to participants interrupted by non-painful stimuli. Further, they would report lower motivation to perform the interrupted activity.

Results can be readily summarized. The two groups did not differ with regards to time spent away from the interrupted ongoing task and total time to complete the experimental task (i.e., the ongoing task including the time on the interruption task). Reported motivation for the interruption task was somewhat higher than for the ongoing task, but did not differ between the

two groups. Our hypotheses were thus not confirmed. Further, in contrast to our expectations and to a previous study (13), pain catastrophizing did not emerge as an important factor in the consequences of interruptions by pain on performance. Its potential role thus warrants further investigation.

A theoretical model of activity interruptions by pain predicted that these will have negative consequences (3). Further, previous research has shown that people with pain respond to interruptions of work-related activities by continuing these activities outside work hours (12); in other words, by adjusting the way in which they allocate time to their activities that are interrupted by pain. Our results, however, suggest that activity interruptions by pain do not necessarily lead to adjustments in the pattern of activity performance more than activity interruptions by pain-irrelevant stimuli do. Our finding also deviates from existing evidence that pain impairs concurrent task performance more than control stimuli (such as non-aversive somatic stimulation (34), or aversive auditory stimulation (35)).

On the other hand, our finding is in line with recently published studies showing that activity interruptions by pain and by non-pain impair quality of performance (expressed in accuracy and reaction times) to a similar degree (10,11). One explanation might be that pain affects task performance only instantly, but does not have a delayed effect (36). Further, it is possible that people are to a certain degree resilient to the negative consequences of activity interruptions by pain. That might especially be the case in a group of young and healthy participants and when the interrupted task is fairly easy, as in the present study. Studies from outside the field of pain have shown that, even though interruptions are mostly disruptive (4,5,8), they may sometimes improve performance, especially when the interrupted task is very easy, boring or repetitive (37,38), as the current ongoing task might have been. Although recent data shows that interruptions by pain are

not more disruptive for the performance of a fairly complex activity compared to interruptions by non-pain (11), the same might not be true as regards performance pattern.

Another task characteristic might also explain our results, at least partly. Specifically, the completion point of our ongoing task was clearly defined, and could not be avoided unless the participant chose to terminate the lab session. This is in contrast to the open-ended ongoing task with one interruption of fixed duration that was used in the study of Schrooten and colleagues (13). It is plausible that when a task must be completed but is interrupted by pain, and the option to complete it by different means (e.g., by delegating it to another person) is unavailable, the person tries to complete it efficiently by avoiding long breaks that might impair performance and cause further delays (39).

The expected negative consequences of activity interruptions by pain might not necessarily be visible in the performance of the interrupted task, for example because people anticipate the negative effects and try to compensate for them (17). Research from outside the field of pain suggests that performance decrements caused by interruptions can be prevented and even reversed if one adapts their working strategy, but that this can lead to the experience of higher stress, frustration, annoyance, and perceived effort invested in the task (6,7,40). In the same manner, interruptions by pain might not necessarily impair performance accuracy or performance pattern more than interruptions by non-pain, as this and previous research has shown (10,11), but may have (more) negative emotional consequences. The inherent unpleasantness of pain (41) in combination with the (potential) use of compensatory strategies to prevent anticipated performance decrements might give rise to negative affect after interruptions by pain. In partial support of this idea, our exploratory data shows that negative affect persisted across the lab session in participants who were interrupted by pain, whereas it decreased in participants who were interrupted by the

non-painful stimuli. Future research can further delve into this topic, for example by measuring specific affective states (e.g., specifically frustration rather than generically negative affect), by measuring affect immediately after an interruption (instead of upon completion of the whole activity), and/ or by disentangling the affective consequences of activity interruptions by pain from these of pain itself (e.g., by comparing activity interruptions by pain with pain that is not followed by an interruption).

The observation that participants preferred the interruption task over the ongoing task can be explained by task characteristics. The repeated interruptions that occurred during the ongoing task might have rendered it more unpleasant, and thus less motivating, than the interruption task, irrespective of the type of stimulus that prompted the interruption. Further, participants might have found the rapid change of screen configuration in the interruption task more interesting than the ongoing task, which might have been perceived as slower. The role of the motivational value of both the interrupted and the interrupting task is an interesting avenue for future research. Recent studies indicate that pain-related avoidance is reduced in the presence of valued goals (16,42). As pain does not occur in a motivational vacuum, it would be informative to investigate task preferences (e.g. in terms of time spent on task) as a function of the motivational value of the interrupted and the interrupting task.

This study is not without limitations. Firstly, as mentioned above, the ongoing task was relatively easy. It is possible that people interrupted by pain take longer breaks when the task imposes higher (cognitive) load. Also, we considered physical tasks to be relevant to the daily life of people with pain and thus explicitly aimed at simulating a motoric task with a clear completion point. However, our paradigm is a laboratory task and might thus lack in ecological validity. Future research may investigate task type and/or load as factors moderating the effects of interruptions by

pain (3). Secondly, the non-pain control stimulus that we used was a bell sound that differed from the painful stimulation not only in aversiveness, but also in modality. A control stimulus that differs with respect to only one dimension might have been preferred. Previous research, though, has provided evidence for the pain-specificity of the interference effects of pain. For example, Forkmann and colleagues (35) found that pain causes greater impairment in visual encoding than auditory stimuli matched to pain for unpleasantness. In any case, it is recommended for future research to use control stimuli matched to pain in as many dimensions possible. Similarly, future research may replicate the present study with tonic pain stimuli (such as heat pain), which may approach the chronic pain experience more closely. Third, our findings might not readily generalize to clinical samples, because our sample consisted of healthy volunteers. Further, as our study was adequately powered to detect large effects, it is possible that small or moderate effects exist, but could not be captured in this experiment. It would be worthwhile for future research to replicate the current findings with bigger and potentially more diverse samples.

To our knowledge, this is the first experiment that compared interruptions by painful stimuli to interruptions by non-painful stimuli with regards to their effect on the pattern of activity performance. Although activity interruptions by pain probably contribute to (chronic) pain patients' disability to a significant degree, they have not been systematically investigated. The findings of research on activity interruptions by pain can potentially be used for the better management of interruptions by pain. This severely understudied area deserves scientific attention.

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Conflict of interest /Disclosures

All authors have discussed the results and commented on the manuscript. The authors have no conflict of interest to report. We report all data exclusions, all manipulations, and all measures in the study.

Ethical issues

The study described in the present manuscript was approved by the appropriate Ethical Board (Social and Societal Ethics Committee, reg. nr. S54157, and Medical Ethics Committee of the University of Leuven, reg. nr. ML8125). Participants provided informed consent prior to participation.

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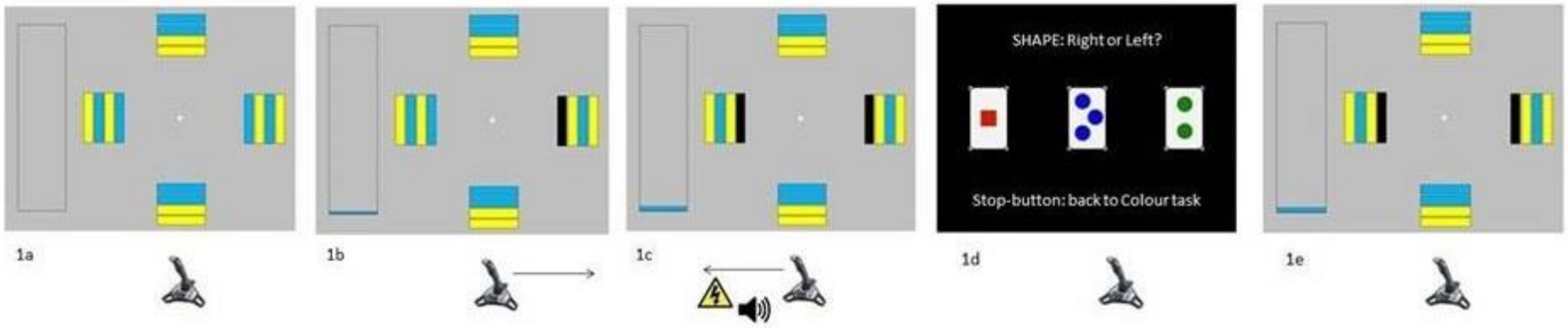
Figure 1. Schematic representation of the ongoing task and interruption task trials.



Legend.

Participants view rectangles on four locations on the computer screen, which correspond to four joystick movements (panel 1a). With every movement, the first available rectangle at the matching location becomes black, and thus unavailable. In addition, with every movement to a rectangle of the target colour (in this example: blue), the bar on the left side of the screen gets fuller with colour (panel 1b). Participants are instructed to prioritize target colour rectangles, and to colour the vertical bar completely in order for the task to be completed.

On randomly preselected trials, the interruption cue (painful stimulus or non-painful, non-aversive auditory stimulus) is delivered during the movement (panel 1c). Upon interruption cue offset and movement completion, the interruption task is initiated (panel 1d). During the interruption task participants are asked to categorize cards according to the shapes depicted on them. Every interruption task block has a maximum duration, but participants can stop it earlier by pressing the Stop-button on the joystick. The ongoing task is then resumed at the same point where it was left off (panel 1e).

Figure 2. Mean time on interruption task per group, in seconds. Error bars depict standard errors.

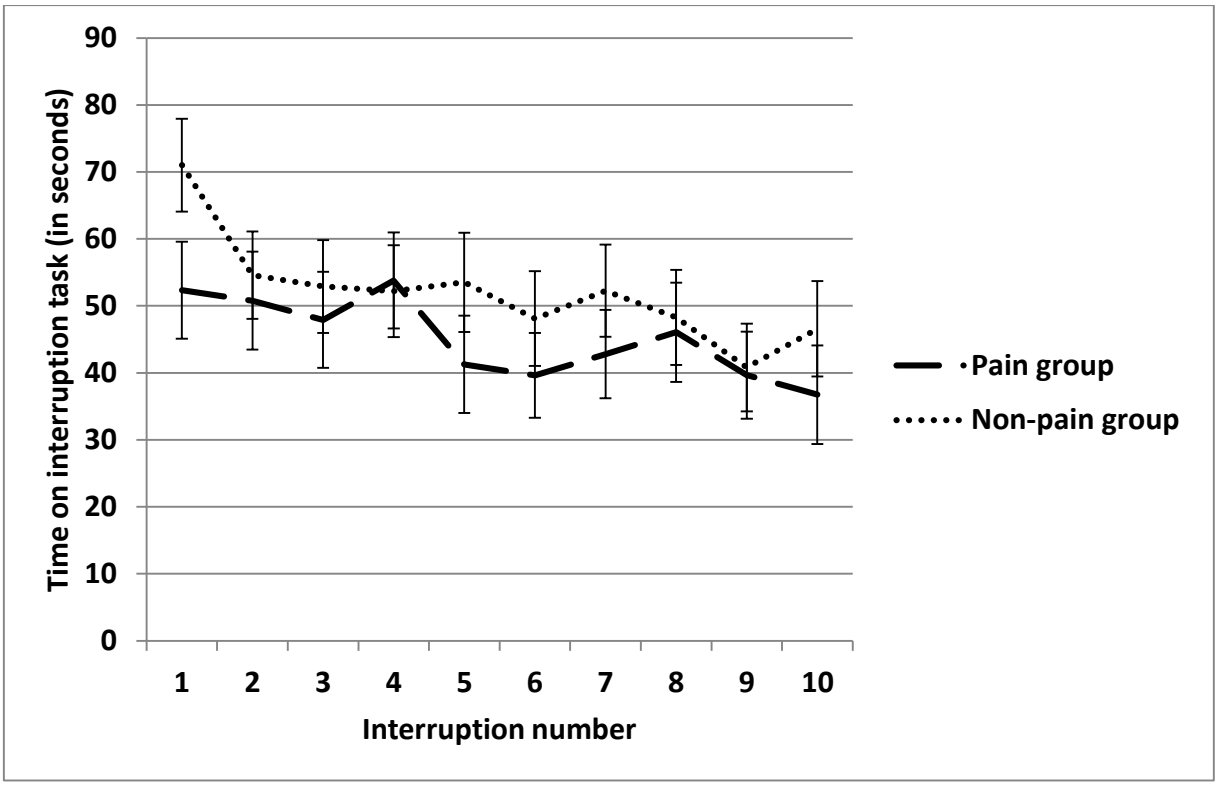


Table 1.

Sample characteristics (ratio or mean with SD and range in parenthesis) per group, and group comparisons

	Pain (*n*=29)	Non-pain (*n*=31)	Group comparison
Females / Males	22 / 7	21 / 10	$\chi^2(1) = 0.49$, $p=.57$
Age	21.52 (2.77, 18-28)	20.23 (2.69, 18-33)	$t(58) = -1.83$, $p=.07$
PCS score	17.90 (7.96, 5-37)	18.47 (8.94, 0-35) [a]	$t(57) = 0.26$, $p=.80$

Note. PCS = Pain Catastrophizing Scale

[a] *n*=30 (one participant did not complete the online questionnaire session).

Table 2

Interruption cue characteristics (mean, with SD and range in parenthesis) per group, and group comparisons (t-tests with mean differences and 95% CIs)

	Pain (*n*=29)	Non-pain (*n*=31)	Group comparison
Painfulness	7.52 (1.50, 3-10)	(not rated)	-
Unpleasantness	8.59 (1.18, 5-10)	2.10 (1.97, 0-7)	$t(49.59) = -15.58^{*}$, $p<.001$
			6.49 [5.65, 7.33]
Threat value	5.93 (2.39, 2-10)	1.61 (1.65, 0-6)	$t(58) = -8.2^{*}$, $p<.001$
			4.32 [3.25, 5.39]

Note. Interruption cue Painfulness / Unpleasantness / Threat value were rated retrospectively on 11-point numerical scales (0=not at all; 10=to a very large degree)

Table 3

Self-reported state affect across the lab session (mean, with SD and range in parenthesis).

	Pain (*n*=29)			Non-pain (*n*=31)		
	Beginning session	After calibration	End session	Beginning session	After calibration	End session
SAM Pleasure	6.9 (1.0, 5-9)	6.2 (1.3, 4-9)[a]	6.5 (1.1, 5-9)	7.0 (1.1, 4-9)	6.9 (1.0, 5-9)[a]	6.4 (1.0, 4-8)
SAM Arousal	3.6 (1.7, 1-7)	4.5 (1.6, 2-8)[a]	3.9 (1.8, 1-9)	3.4 (1.7, 1-6)	3.3 (1.8, 1-7)[a]	3.1 (1.6, 1-6)
SAM Dominance	5.4 (1.1, 2-7)	5.1 (1.0, 3-7)	5.3 (0.9, 3-7)	5.7 (1.6, 2-7)	5.8 (1.2, 4-8)	5.4 (1.5, 1-8)
PANAS Positive	32.9 (7.0 18-44)	-	29.8 (6.8, 18-40)	31.4 (5.3, 16-43)	-	27.4 (6.4, 13-39)
PANAS Negative	13.2 (2.8, 10-22)	-	13.2 (3.7, 10-24)	13.5 (2.9, 10-21)[b]	-	11.8 (2.5, 10-18)[b]

[a] columns differ at $p < .05$ [b] columns differ at $p < .001$

Note 1. The possible score range for each SAM scale is 0-9, whereas for each PANAS subscale it is 0-50.

Note 2. Because of its length and the exploratory nature of the measurements, the PANAS was administered only at the beginning and end of the session.

SUPPLEMENTARY MATERIAL

Results of covariance analyses

In order to test our hypothesis that effects of activity interruptions by pain would be more prominent amongst high pain catastrophizers, we centered participants' PCS score and included it as a continuous variable in our analyses (see main manuscript, *2.7 Statistical analyses*). The results of these covariance analyses were as follows:

S.1 Interruption effects: Covariance analyses

S.1.1 Time on the interruption task

Adding the (centered) PCS score to the analysis did not change the results essentially and did not yield new significant results, indicating that pain catastrophizing did not in any way influence the effects of activity interruptions by pain on the duration of the interruption [main effect interruption number: $F(9, 47) = 4.13$, $p = .001$, $\eta_p^2 = .441$; main effect interruption cue group: $F(1, 55) = 0.71$, $p = .403$, $\eta_p^2 = .013$; main effect PCS: $F(1, 55) = 0.05$, $p = .826$, $\eta_p^2 = .001$; interaction interruption number*interruption cue group: $F(9, 47) = 1.95$, $p = .067$, $\eta_p^2 = .272$; interaction interruption number*PCS: $F(9, 47) = 0.64$, $p = .759$, $\eta_p^2 = .109$; interaction interruption cue group*PCS: $F(1, 55) = 0.06$, $p = .808$, $\eta_p^2 = .001$; interaction interruption number*interruption cue group*PCS: $F(9, 47) = 1.00$, $p = .452$, $\eta_p^2 = .161$].

S.1.2 Total time to complete the experimental task

Adding the (centered) PCS score to the analysis did not change the results essentially and did not yield new significant results, indicating that pain catastrophizing did not in any way influence the effect of activity interruptions by pain on the time needed to complete the experimental task (main effect interruption cue group: $F(1, 51) = 0.49$, $p = .486$, $\eta_p^2 = .10$; main

effect PCS: $F(1, 51) = 0.50$, $p = .481$, $\eta_p^2 = .10$; interaction interruption cue group*PCS: $F(1, 51) = .01$, $p = .947$, $\eta_p^2 = 0$).

S.1.3 Self-reported motivation

Adding the (centered) PCS score to the analysis did not change the results essentially and did not yield new significant results, indicating that pain catastrophizing had no influence on the effects of activity interruptions by pain on (self-reported) motivation to perform either the (interrupted) ongoing task, or the interruption task (main effect task type: $F(1, 55) = 9.46$, $p = .003$, $\eta_p^2 = .147$; main effect interruption cue group: $F(1, 55) = 0.37$, $p = .545$, $\eta_p^2 = .007$; main effect PCS: $F(1, 55) = 1.83$, $p = .181$, $\eta_p^2 = .032$; interaction task type* interruption cue group: $F(1, 55) = 1.39$, $p = .243$, $\eta_p^2 = .025$; interaction task type*PCS: $F(1, 55) = 0.31$, $p = .579$, $\eta_p^2 = .006$; interaction interruption cue group*PCS: $F(1, 55) = 2.41$, $p = .126$, $\eta_p^2 = .042$; interaction task type* interruption cue group*PCS: $F(1, 55) = 1.47$, $p = .231$, $\eta_p^2 = .026$).

S.1.4 Stop-button presses during the interruption task

Adding the (centered) PCS score to the analysis did not change the results essentially and did not yield new significant results, indicating that pain catastrophizing did not influence the number of times that participants decided to stop the interruption task themselves (rather than perform it for the full 2 minutes) (main effect interruption cue group: $F(1, 55) = 0.34$, $p = .561$, $\eta_p^2 = .006$; main effect PCS: $F(1, 55) = 0.08$, $p = .783$, $\eta_p^2 = .001$; interaction interruption cue group*PCS : $F(1, 55) = 7.91$, $p = .293$, $\eta_p^2 = .020$).